FERMILAB-LU-144

A COLLAGE

OF

SCC LINAC TUNING

(Prototype II Cold Model)

Introduction The following note describes some of the aluminum model measurements made on accelerating cells and side cells to date. Fig. 1 is an outline of the Prototype II test cavity being constructed. A middle assembly with flat blank off plates represents the basic $\pi/2$ cell measured.

Cell ID' Fig. 1 represents the basic structure to be manufactured. It consists of interior or middle Acc cells labeled PAMxx,yy. End Acc cells are labled PAExx if they are terminating 1/2 cells and PAEBxx if they are end cells that couple to a bridge coupler. Coupling cells are made up of two halves labled PASxx,yy. The letters P,A,M,E,B,S are identifiers. P=prototype, A=aluminum, M =middle cell, E=end cell, B=bridge coupler cell, S=side cell.

General Procedure The cell geometry was calculated using Superfish. Half cells were machined and their frequencies measured and compared with Superfish calculations. Coupling slots of four depths were machined into the cells and the resultant frequency shift and coupling constant was measured. The $\pi/2$ mode was measured for a basic interior cell terminated with a flat plate. A stack of up to six cells was measured and the $\pi/2$ frequency was projected to that of an infinite stack. Starting with 805.954 MHz. the final frequency, as expected, was too low. Summary 1 and Table 1 lists a first set of data. Expected values (Summary 2) were developed by scaling from the final frequency of 789.548 MHz. to 805.000 MHz. A geometry change was determined with the new superfish frequency and parts remachined. The final results are in Summary 3 and Table 2.

Summary Description The following notes describe the measurements or calculations at each of the numbered boxes on the summary sheets.

1 SF Calculation These are the calculated frequencies that correspond to the mechanical part dimensions. A Superfish mesh of 0.030 inches produced the nearest match to a selection of parts machined. Finer mesh might be desirable but requires more computer memory than we have available. For the present this seems adequate.

2 SF Calculation Adj. The SF value was divided by 1.000315 to compare measurements in the lab. The average room temperature, humidity and atmospheric pressure were adequate for the first pass at these measurements. No temperature control was required of the machine shop. Later, when it seems necessary, corrections will be introduced.

3. <u>1/2 Cell SF Config.</u> These data show the half cell measurements on as machined parts prior to slotting. Twelve cells were available for Summary1. Only 4 measurements were available when going to 821.719 MHz. since four of the six interior cells had previously been slotted.

4. <u>1/2 Cell 5% Slot.</u> These measurements were made with flat plates over the accelerating cells. One of the two gaps was alternately shorted and the opened cell measured. Initially the measured cell was vented to free space. Later it was found to be more consistent to measure the frequency with a side cell filled with an RF absorber installed on the assembly. That change, after Summary 1 measurements, accounts for some of the larger differences in the expected values and measured values between Summaries 2 and 3.

5. <u>Single Module π/2 Freq.</u> The π/2 mode was measured for each of the interior modules and the average is presented here. Tuning techniques are being developed to fine tune these modules to be identical at the correct frequency.

6. <u>Stacked Module π/2 Freq.</u> When the basic interior modules are stacked and terminated with a half cell the π/2 frequency is lowered (Side cells are stacked alternately on opposite sides). That is because the image cell at the end plates raises that cell above the interior cell frequency. The available modules were stacked and measured.

7. <u>Inf. Module π/2 Freq.</u> The π/2 frequency of the internal structure is determined by stacking n=1,2,.....,n 1/2 cells. Measuring the π/2 frequency for each n and plotting the data. Projecting the value to n= inf. gives the interior cell frequency. A plot of π/2 vs n (the number of 1/2 cells) is shown in Fig. 2 for Summary 3. The final π/2 frequency was 803.997 MHz, i.e., lower than the 804.080 MHz projected from the graph when the stack was tuned properly with full end cells.

8. <u>Inf. Module π/2 Freq. Vac.</u> Multiplying by the average 1.000315 correction establishes the structure frequency expected at 25 deg. C and vacuum.

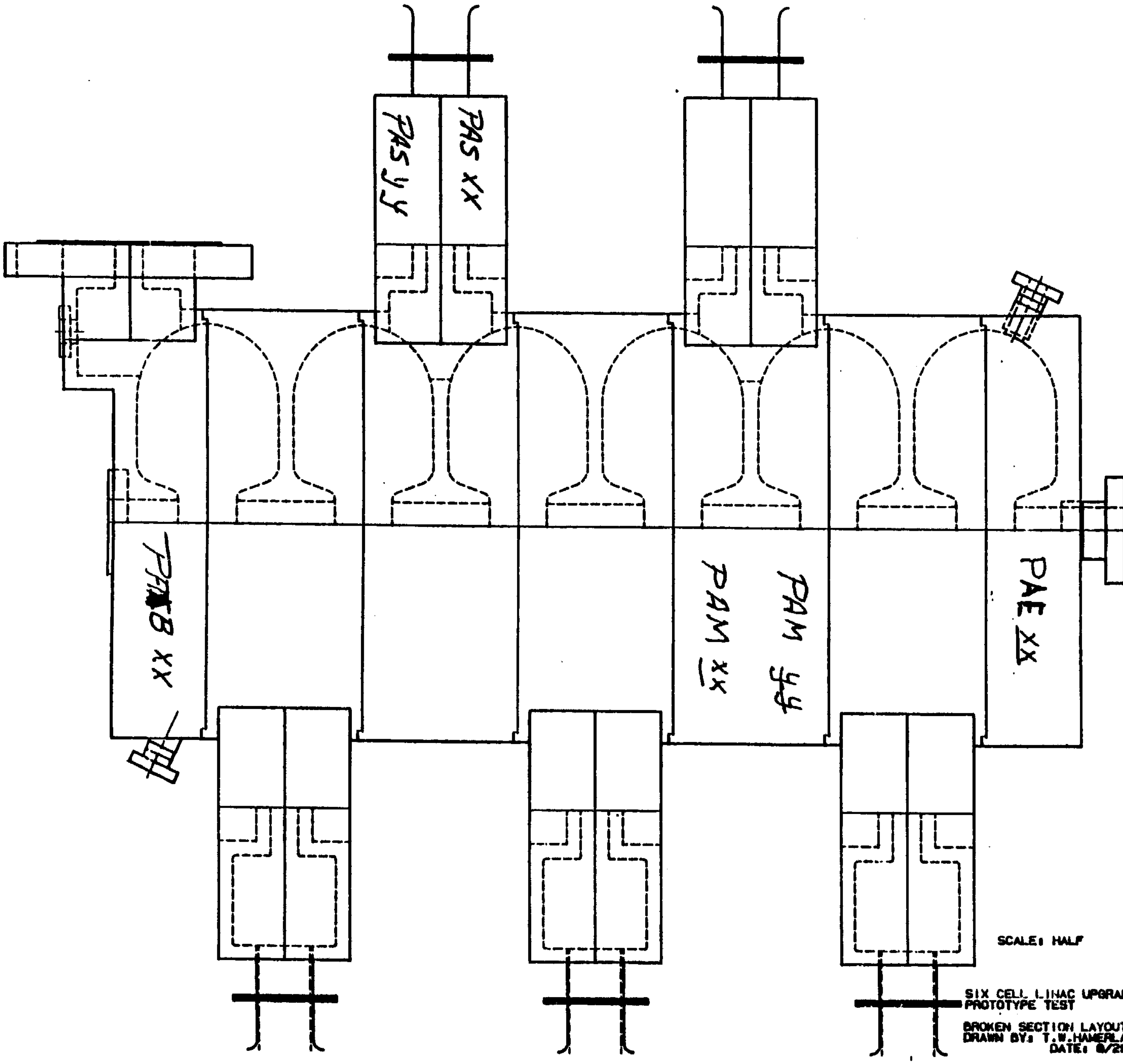
The cold model is presently in range to extrapolate frequencies to the copper Prototype II. Further work on the cold model in parallel with copper machining will continue. It is expected that as few as two aluminum middle sections will be needed at each beta to extrapolate copper dimentions for the full machine. Perhaps, if we get good at it, we can just use measurements of copper at stages of the fabrication to extrapolate the dimentions.

<u>Stack of Seven Accelerating Cells</u> The available cells were stacked with full end terminations, Fig. 4. At first the stacking was random. Later the cells, by rearranging the stack, were paired so that the spread in accelerating cell frequencies were more uniform (pair average improved from a spread of 330 to 61 KHz.) This technique will be useful for final assembly of copper parts. Fig. 5 diagrams the original and rearranged stack. Table 3 lists the frequencies measured in the cold model.

With the accelerating cells tuned this close a dispersion curve was measured and the side cells were tuned to provide a closed stopband. Fig. 6 shows a typical set of modes for 7 acc and 6 side cells. Table 4 lists the mode frequencies along with calculations of the fit to the dispersion curve as provided by Disper (a Los Alamos dispersion fit program). In this case a fit using two frequencies (acc cell and coupling cell) and nearest neighbor, accelerating cell and coupling cell coupling constants K1,K2 and K3 was used.

With reasonable agreement to the theory, it was time to make a bead pull. That is, a measurement of field uniformity of all the cells. Fig. 7 shows the expanded phase excursion as a bead is pulled through the cavity gaps. In the center region one out of five gaps are off by 0.25%. We have not yet tracked down the error. The ends are high by about 4.88%. This is due to the method of tuning. That is , the end 1/2 cell in a stack has the spacing of the interior cells. The terminating end has a longer nose cone since it tunes to nearly $\pi/2$ without the offset of the interior cells. We have decided to correct this by making the nose cones all identical and lowering the end terminating cell by carving out the wall near the O.D. of the cell. This is underway in the copper Prototype II.

A,C B,5,E,M 1-7: 1-4 01



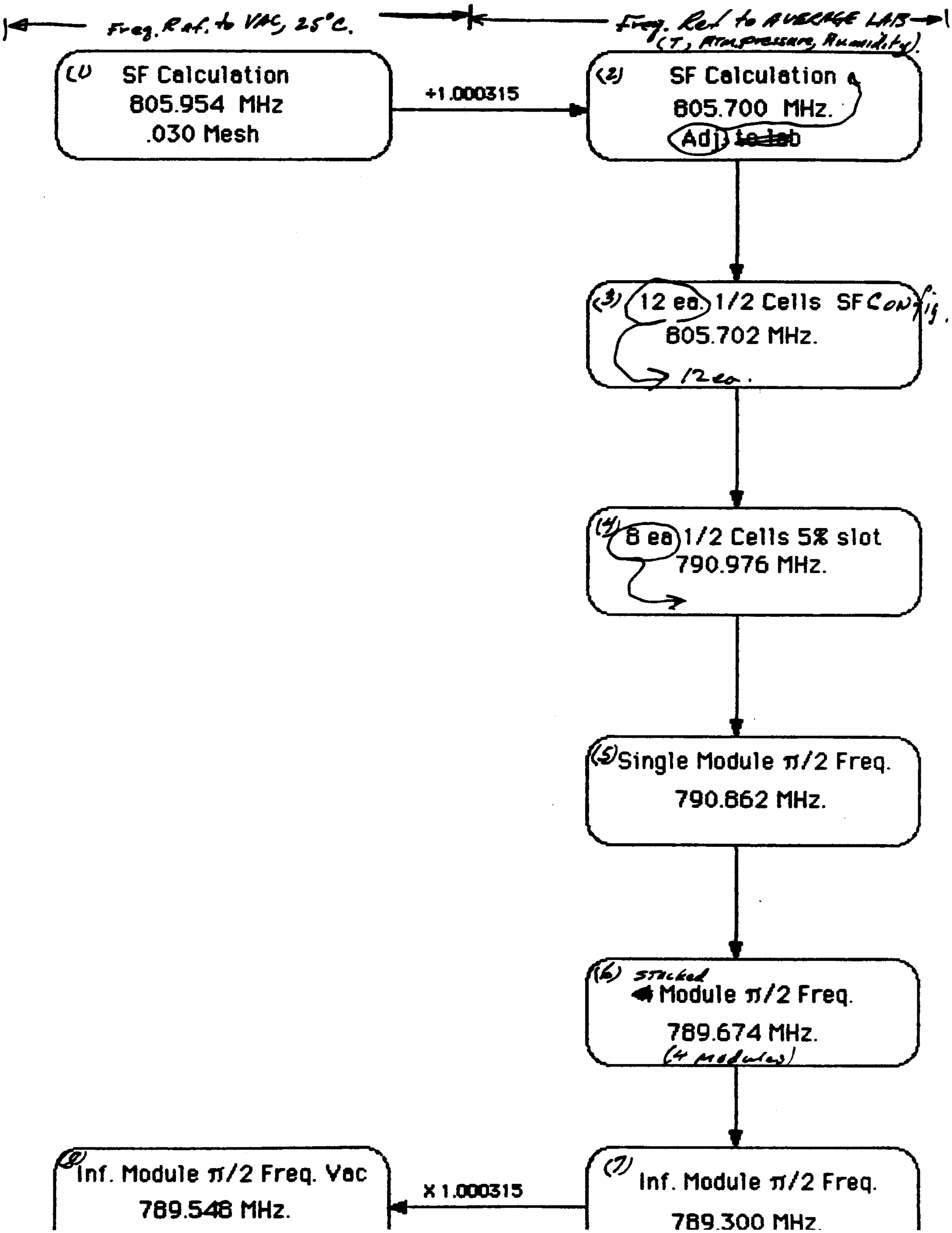
SCALE: HALF

SIX CELL LINAC UPGRADE
PROTOTYPE TEST
BROKEN SECTION LAYOUT
DRAWN BY: T.W.HAMERLA
DATE: 8/29/

Fig 1

SUMMARY I

Cold Test Frequency Measurements (805.954 MHz.)



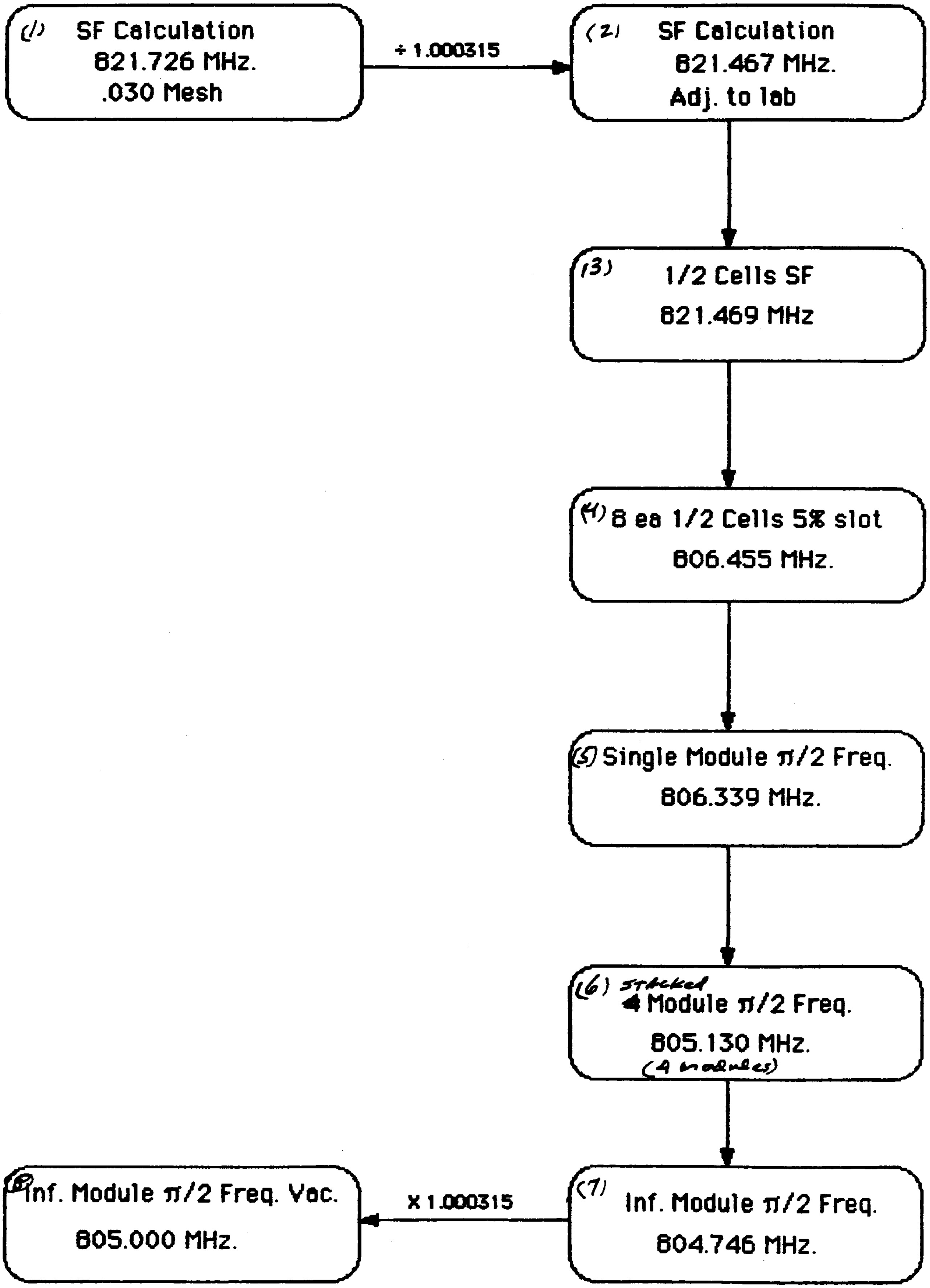
5% SLOT Δf's (805.954)

Cell ID	SF Meas. Freq.	5% Slot Freq.	Pair Avg.	π/2 open	π/2 w/side
PAM01	805.642				
PAM02	805.838				
		PAM 01,02,03,04 not slotted until after 821.719 nose cone			
PAM03	805.617				
PAM04	806.262				
PAM05	805.63	791.065			
			790.8825	790.449	790.845
PAM06	805.614	790.7			
PAM07	805.543	790.803			
			790.8815	790.378	790.774
PAM08	805.601	790.96			
PAM09	805.801	791.01			
			791.0415	790.545	790.943
PAM10	805.701	791.073			
PAM11	805.569	790.95			
			791.0975	790.494	790.886
PAM12	805.722	791.245			
Average	805.65	790.98	790.98	790.47	790.86
std dev	0.09	0.17	0.11	0.07	0.07
Min	805.54	790.70	790.88	790.38	790.77
Max	805.80	791.25	791.10	790.55	790.94
Spread	0.26	0.54	0.22	0.17	0.17
For stacked modules terminated in 1/2 cells					
# modules	1/#cells	π/2 Freq			
1	0.5	790.862			
2	0.25	790.107			
3	0.166666	789.857			
4	0.125	789.676			
Acc Nose Δf/Δs=238 KHz./mil					

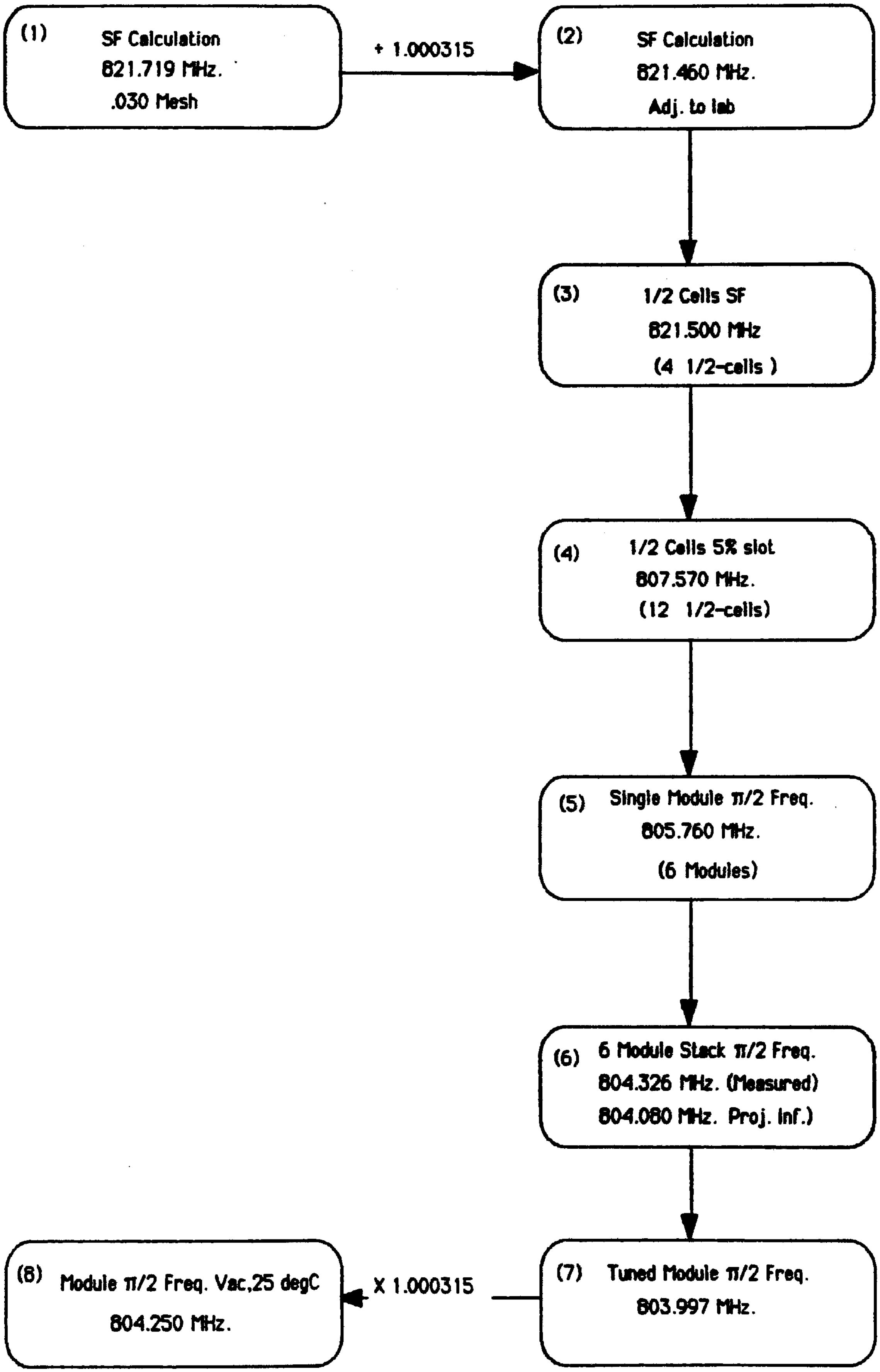
TABLE 1

Summary. 2

Expected Frequencies for 805.000MHz. Inf. Stack



Prototype II Cold Test Frequency Measurements (821.719MHz.)



(SUMMARY 3)

5% SLOT ∆f's (821.719)

Cell ID	SF Meas. Freq.	5% Slot Freq.	Pair Avg.	π/2 w/side
	Original	SF=821.719		
PAM01	821.376	807.563		
			807.618	805.794
PAM02	821.538	807.673		
PAM03	821.493	807.702		
			807.7535	805.919
PAM04	821.59	807.805		
PAM05		807.501		
			807.4945	805.682
PAM06		807.488		
PAM07		807.403		
			807.425	805.614
PAM08		807.447		
PAM09		807.691		
			807.623	805.806
PAM10		807.555		
PAM11		807.462		
			807.5235	805.715
PAM12		807.585		
Average	821.50	807.57	807.57	805.76
std dev	0.09	0.12	0.12	0.11
Min	821.38	807.40	807.43	805.61
Max	821.59	807.81	807.75	805.92
Spread	0.21	0.40	0.33	0.30
For stacked modules terminated in 1/2 cells				
# modules	1/#cells	π/2 Freq		
1	0.5	805.7		
2	0.25	804.9		
3	0.16666667	804.5737		
4	0.125	804.446		
5	0.1	804.391		
6	0.08333333	804.3261		
Acc nose ∆f/∆s= 215 KHz./mil				

TABLE 2

821 π/2 vs n

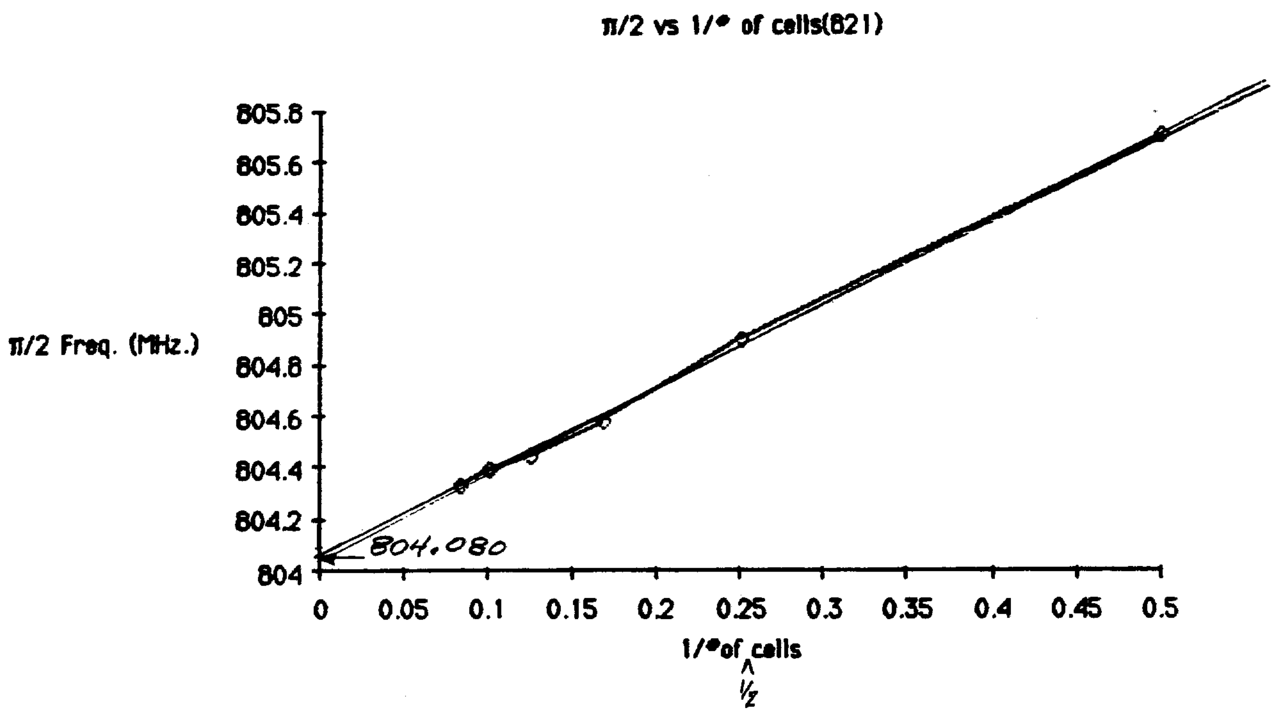
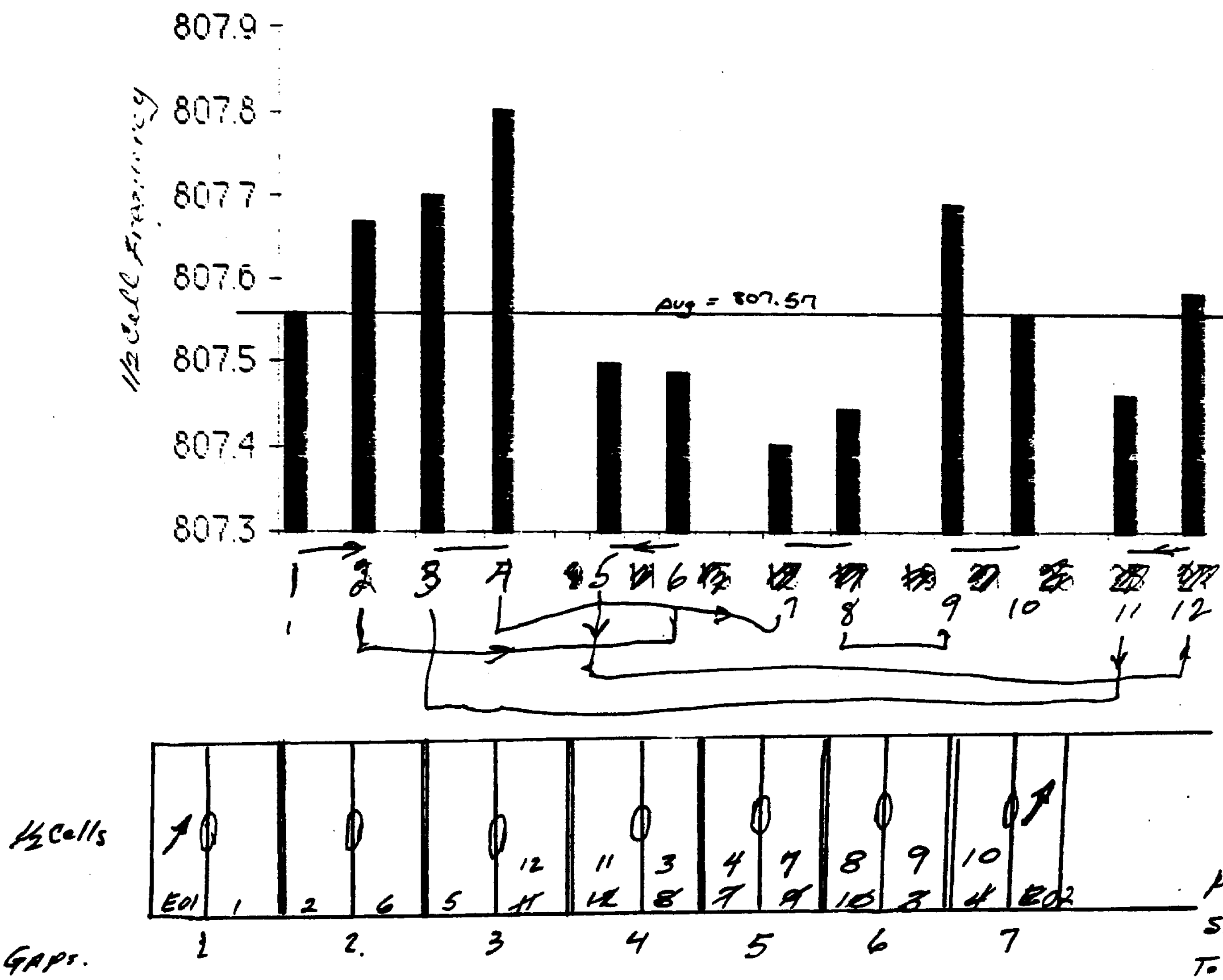


Fig 2.

HALF CELL CHART

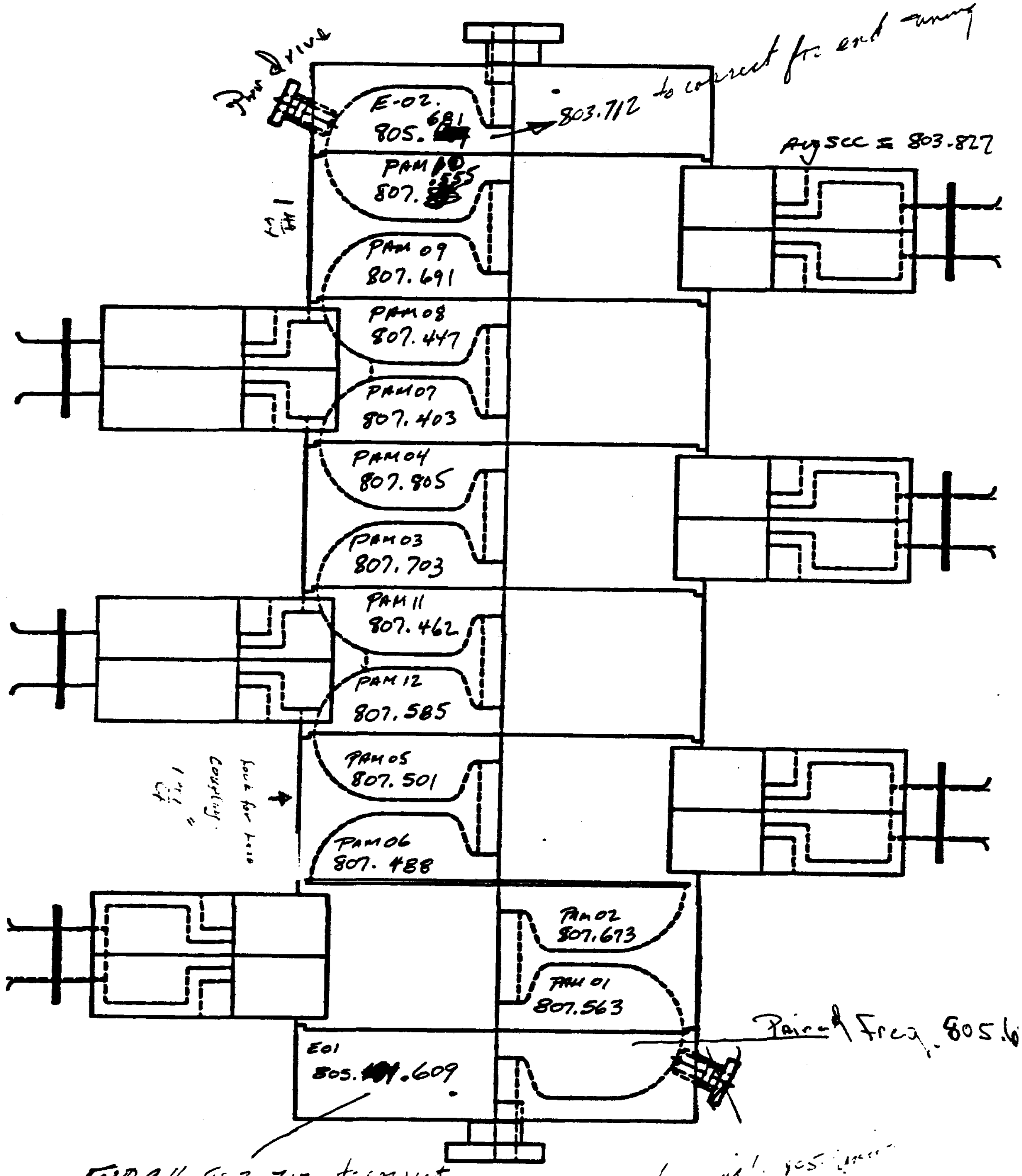


New stacking To bal. pair freq + Avg E to Mean Val

0 = gaps

Fig 5

STACKing ORDER



End Cell = 803.712 to correct for end tuning.
$\pi/2$ = 803.997.

→ End cell = 804.714 for ... pos ...
$\pi/2$ = 803.997

Fig 4.

5% SLOT Δf Restack

(1) Cell ID	(2) 5% Slot Freq.	(3) Internal Cells	(4) Pair Avg.	(5) Pair Avg. Meas.	(6) Pair Avg. Meas.
			Calc	All other Shorts	All other Shorts
				untuned	tuned
PAE01	805.609	1/2 cell			
		807.563	806.586	806.667	805.684
PAM01	807.563				
PAM02	807.673				
		807.5805	807.5805	807.344	807.344
PAM06	807.488				
PAM05	807.501				
		807.543	807.543	807.304	807.304
PAM12	807.585				
PAM11	807.462				
		807.5825	807.5825	807.299	807.299
PAM03	807.703				
PAM04	807.805				
		807.604	807.604	807.344	807.344
PAM07	807.403				
PAM08	807.447				
		807.569	807.569	807.336	807.336
PAM09	807.691				
PAM10	807.555	1/2 cell			
		807.555	806.618	806.634	805.684
PAE02	805.681				
Average	807.57	807.571			
std dev	0.13	0.0200810766			
Min	807.40	807.543			
Max	807.81	807.604			
Spread	0.40	0.061			

TABLE 3

1 .4-89
Refer to log page 20

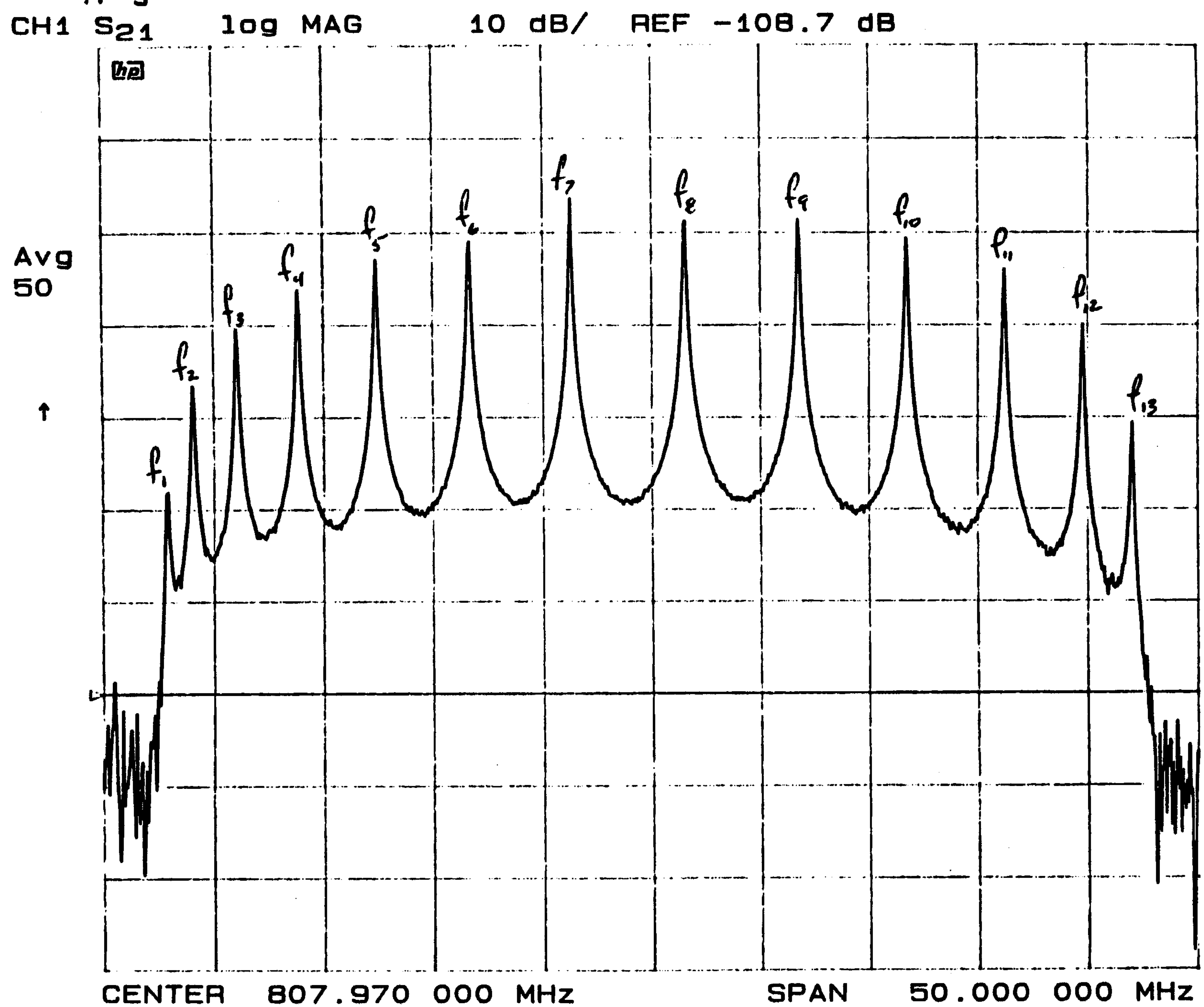


Fig 6

[illegible]
5 1.779062720212788e-03 8.52442e-08
6 1.779062719685383e-03 2.96457e-10
7 1.779062719450478e-03 1.32038e-10
8 1.779062718889908e-03 3.15084e-10
9 1.779062718883459e-03 3.63423e-12
10 1.779062718883459e-03 0.00000

chisq=0.00177906 nit=10 err=0.00000
The average frequency difference is 3.308788e-02

w1= 807.41132
w2= 803.63513
k1= 0.055068963
k2= -0.0085641668
k3= 0.00092046192

w1/sqrt(1-k2) = 803.97597
w2/sqrt(1-k3) = 804.00524
delta freq = 0.029275348
TYPE A CHARACTER AND PRESS <RETURN> TO CONTINUE

Ends Retuned for side cell. MIN Energy.
Tuned. Shorts in All other cells.

PAS 05,11	803.6575
	804.0994
	803.6354
	803.8042
PAS 02,10	803.910
PAS 01,03	803.857
	803.827 avg

End1 End. tuning Acc. cell with screw in.
804.805 → 804.050 ← Compare to 804.000 projection.
Δ = .750

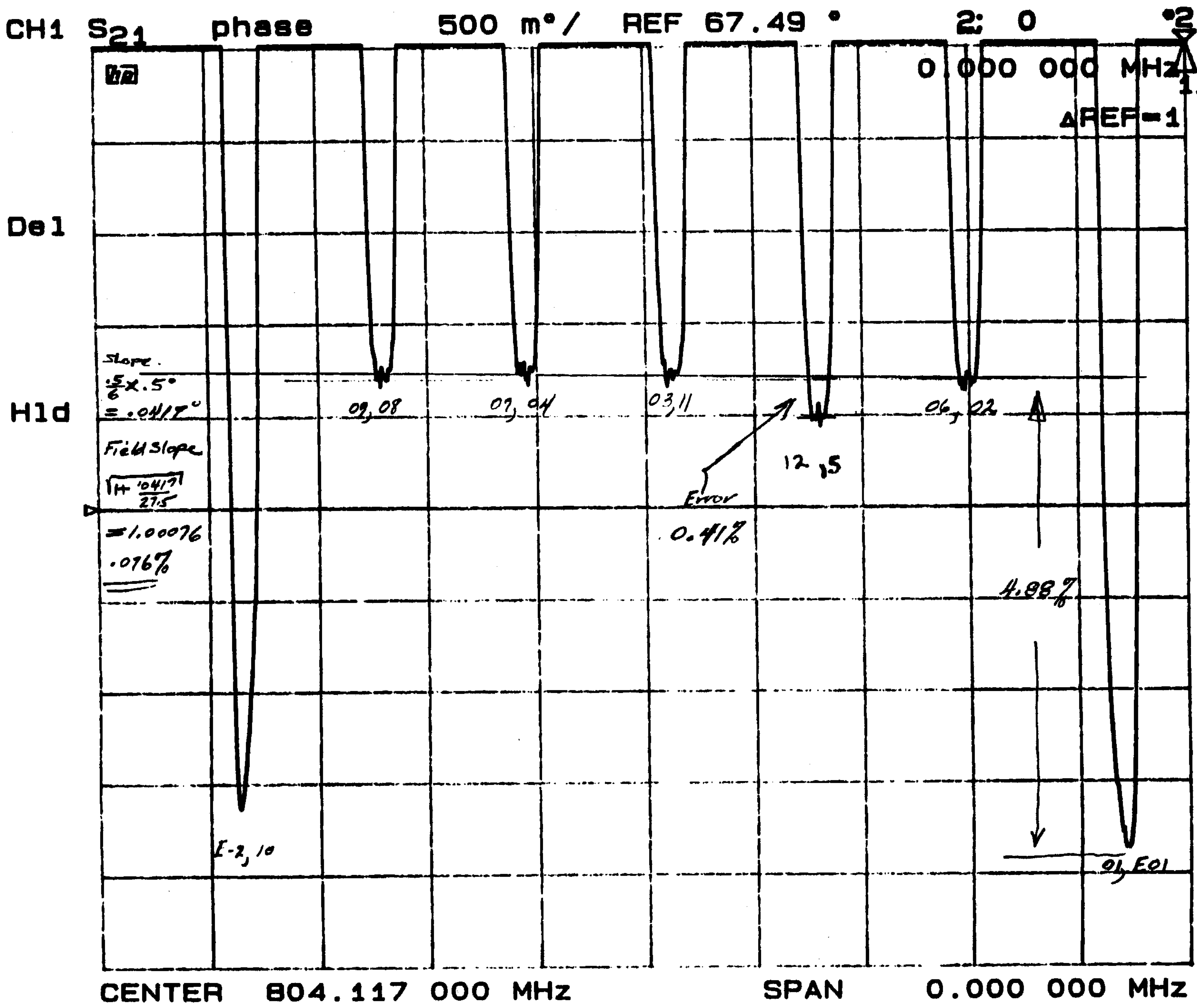
End2. 805.199 → 803.813. ← Too Low?
Δ = 1.386

driving end cells (Acc. 25μs)
803.9024
Δ .0754 — less shorts for [illegible] Cav.

785.735
786.956
788.855
791.586
795.145
799.285
$\frac{\pi}{2}$ 803.976
809.125
814.380
819.385
823.921
827.607
829.882

TABLE 4

WITH AMPLIFIER



$\frac{\pi}{2}$ ctr 804.1236 MHz

Bead centered in gap lowers Freq. ~ 17 KHz

E-2 tuned
E-1 High ≈ 7x125kHz

Full $\Delta\phi \approx 27.5°$

E_1

End gap
.8585/1.772
1.6305
MID GAPS.
.8585x2
1.717

Fig 7

$R = \frac{1.6305}{1.717} = .9496$